Deep-Sea Research II 51 (2004) 1421–1434

DEEP-SEA RESEARCH
PART II

www.elsevier.com/locate/dsr2

The commercial harvest of krill in the southwest Atlantic before and during the CCAMLR 2000 Survey

Christopher D. Jones[a,*], David C. Ramm[b]

[a]Southwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, 8604 La Jolla Shore Dr., La Jolla, CA 92037, USA

[b]Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), 137 Harrington Street, Hobart, Tasmania 7000, Australia

Accepted 18 June 2004
Available online 15 September 2004

Abstract

A brief history of the commercial harvest and fishing patterns for krill (*Euphausia superba*) in the Atlantic sector (Area 48) of the Southern Ocean is presented, with an emphasis on the commercial activities of the krill fishery at the time of the CCAMLR 2000 Survey. During the period of the CCAMLR 2000 Survey, commercial krill fishing activities were centered at the South Shetland Islands in the southern Scotia Sea (Subarea 48.1). Fishing patterns, catches, catch rates, and biological information are also presented for the Japanese stern trawler *Chiyo maru No. 5*, which conducted krill fishing operations in the CCAMLR Subarea 48.1 from 31 January to 1 March, 2000. Information on length and maturity composition is summarized for five regions adjacent to the South Shetland Islands where the *Chiyo maru No. 5* fished. The biological information collected from the commercial fishery agrees well with the findings of the CCAMLR 2000 Survey, as well as with a regional acoustic survey conducted by the US AMLR in Subarea 48.1 from February 22 to March 7, 2000. The relationship between the commercial and survey information emphasizes the value of collecting fine-scale biological information from commercial krill fisheries in the Southern Ocean.

1. Introduction

Commercial fishing for Antarctic krill (*Euphausia superba*) in the Southern Ocean started in the early 1970s following a decade of exploratory fishing. Catches of krill were reported between 1970 and 1973 (up to 7459 t/year; Miller and Agnew, 2000), and comprehensive records of catch and effort have been held by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) since 1973 (e.g., CCAMLR, 1990a). Catches from krill fisheries are usually reported by split-year (July 1 to June 30 of the following year; the year in which a split-year ends is used here as abbreviation).

*Corresponding author. +1-858-546-5605.
E-mail address: cdjones@ucsd.edu (C.D. Jones).

0967-0645/$ - see front matter © 2004 Published by Elsevier Ltd.
doi:10.1016/j.dsr2.2004.06.009

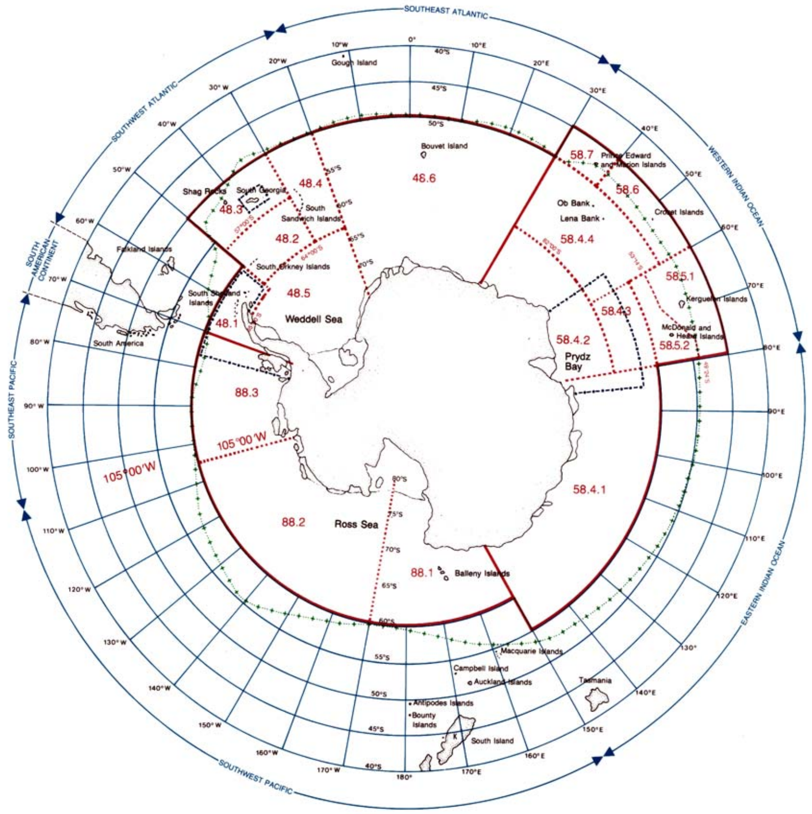

Fig. 1. Map of the CCAMLR Convention area, with statistical areas, subareas, and divisions.

Antarctic krill has been fished in the three major statistical areas of the CCAMLR Convention Area (Fig. 1). Annual (i.e. split-year) catches have averaged 186,239 t (n: 28 years) in the South Atlantic (Area 48), with a peak yield of over 425,871 t in split-year 1986 (Fig. 2). In the southern Indian Ocean (Area 58), catches have averaged 34,400 t (n: 22) and in the Antarctic sector of the Pacific Ocean (Area 88), catches have averaged 3040 t (n: 14). Eighty-seven percent of reported catches of krill have been taken in Area 48.

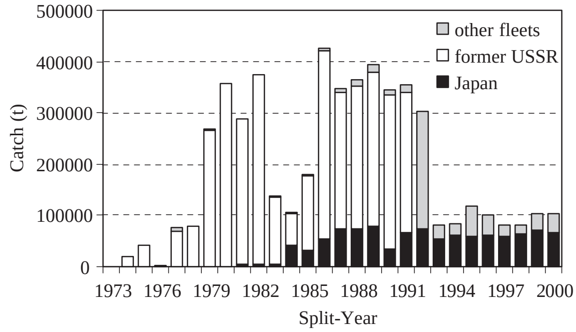

Fig. 2. Commercial catch of krill from Area 48 by split-year (July–June). Source: STATLANT data, CCAMLR.

CCAMLR is actively managing the krill fisheries in Area 48 and Area 58 (Divisions 58.4.2 and 58.4.1). Precautionary catch limits have been set based on the best available scientific information, including the results of the CCAMLR 2000 Survey (a multi-national, multi-ship survey during the austral summer of 2000 to estimate the biomass and distribution of Antarctic krill in Area 48), and the principles encompassing CCAMLRs ecosystem approach to management. These fisheries are considered to be in an early phase of development relative to a potentially fully exploited fishery, given the estimated total available biomass of krill. The current precautionary catch limits for krill are: 4.0 million tonnes in Area 48 (CCAMLR Conservation Measure 32/XIX); 440,000 t in CCAMLR Statistical Division 58.4.1 (106/XIX); and 450,000 t in Division 58.4.2 (45/XX). In addition, the precautionary catch limit in Area 48 has been sub-divided into 1.008 million tonnes in Subarea 48.1, 1.104 million tonnes in Subarea 48.2, 1.056 million tonnes in Subarea 48.3, and 0.832 million tonnes in Subarea 48.4; catch limits will be allocated to smaller management units when catches reach the trigger level of 620,000 t. The catch limit is also sub-divided in Division 58.4.1. Catch and effort data for krill fisheries in the CCAMLR Convention Area are collected by Flag States. Biological data are collected by national scientific observers or observers deployed under CCAMLR's Scheme of International Scientific Observation (CCAMLR, 2001b).

This aim of this paper is to review the fishery trends in Area 48 leading up to the start of CCAMLR 2000 Survey, to describe the pattern of commercial fishing taking place at the time of the survey, and to compare detailed observations by a fishery observer on a commercial trawler with those of the scientific survey. These comparisons serve as a basis toward evaluating how accurately information derived from the commercial fishery for krill represents the status and demographic features of the population. The information reported here is based on data published in CCAMLR's Statistical Bulletin, and data collected by an international scientific observer deployed by the United States on board a Japanese-flagged trawler (Rain, 2000).

2. The krill fishery in Area 48

Two principal fleets have targeted krill in Area 48 (Fig. 2): trawlers from the former Soviet Union from the 1970s to 1991; and the Japanese-flagged trawlers from the 1980s to the present. Other countries have also been involved with this krill fishery, notably Chile (1976, 1983–1994), the Republic of Korea (1987–1992, 1998–present), Poland (1976–1980, 1983, 1986-present), the Russian Federation (1992–1994), and Ukraine (1992–1997, 1999–present).

The krill fishery in Area 48 has been characterized by annual catches exceeding 300,000 t in the 1980s and early 1990s, with a peak of 425,871 t in the 1986 split-year (July 1 1985 to June 30, 1986), and two periods of sharp decline in catches. Relatively low catches in 1983 and 1984 were attributed to the marketing and processing problems, while the dramatic drop in annual catches after 1993 reflected the break-up of the Soviet Union in 1991 and the subsequent removal of fuel subsidies for the Russian and Ukrainian-flagged trawlers (Miller and Agnew, 2000).

The krill fishery in Area 48 is also characterized by a seasonal pattern in fishing. Vessels target krill in the southwest Atlantic, generally fishing in waters adjacent to the South Georgia (Subarea 48.3) during the austral winter, moving southward as the sea ice retreats in spring to fish at the South Shetland Islands (Subareas 48.1) and South Orkney Islands (Subarea 48.2) during summer (Figs. 3 and 4). However, in recent years, the fishing period in Subarea 48.1 has become protracted, and vessels have remained longer in this subarea during the winter months (vessels have fished in June since 1996; July since 1997; August in 2000). As a result, recent activity in the 'winter' fishery in Subarea 48.3 has been low, and no catches of krill were reported over the 19-month period November 1998 to May 2000 (Fig. 4).

2.1. January to March 2000

Between January and March 2000 (Quarter 3 in CCAMLR, 2001a), four commercial fleets targeted krill in the southwest Atlantic (Japan: 4 vessels; Poland: 4 vessels; Republic of Korea: 1 vessel; Uruguay: 1 vessel). Fishing occurred in Subareas 48.1 and 48.2, and no fishing was reported from other subareas in Area 48 (Fig. 5). A total of 26,399 t of krill were caught during these three months, of which 24,957 t (95%) were taken from 27 fine-scale (0.5° latitude by 1.0° longitude) rectangles adjacent to the South Shetlands Islands

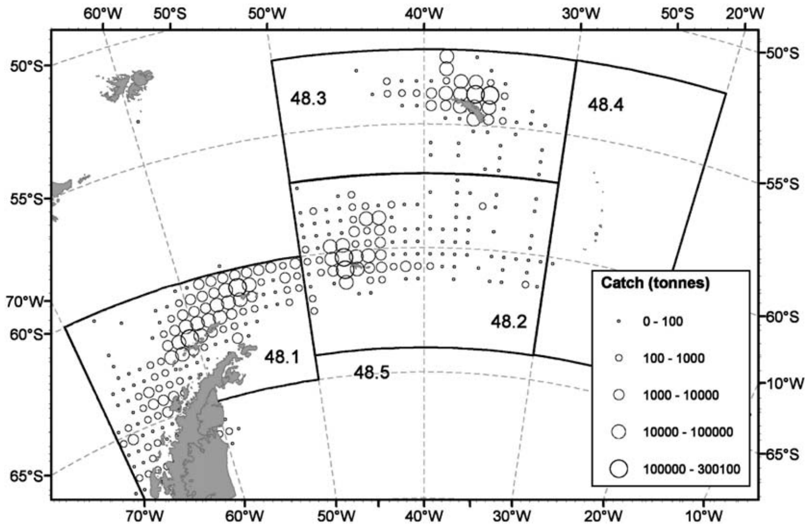

Fig. 3. Commercial catch (t) of krill reported from the southwest Atlantic (Subareas 48.1, 48.2, 48.3, 48.4, 48.5) between the split-years 1974 and 2000. Catches are aggregated by fine-scale (0.5° latitude by 1.0° longitude) rectangles. Source: CCAMLR (1990a,b, 1991, 2001a).

in Subarea 48.1. The remainder of this catch (1442 t) was taken from six fine-scale rectangles in Subarea 48.2 (CCAMLR, 2001a).

Of the 27 fine-scale rectangles fished in Subarea 48.1 between January and March 2000, 23 were traversed during the CCAMLR 2000 Survey (Watkins et al., 2004). The catches reported in these 23 fine-scale rectangles are compared in Fig. 6 and Table 1 with the acoustically derived estimates of krill density from the CCAMLR 2000 Survey. There is a significant correlation ($r_s = 0.366$; $n = 23$; $P < 0.10$) between the ranked catches of krill reported in the 23 fine-scale rectangles and the corresponding ranked mean densities of krill estimated from the CCAMLR 2000 Survey (Fig. 7).

Mean catch rates (catch per unit effort) for fleets fishing for krill in Subarea 48.1 during January to March of each split-year reported, including the 2000 split-year, are plotted in Fig. 8. Because the raw data in Fig. 8 are aggregated by fine-scale rectangle and 10-day period, error bars could not be included around the lines. Two fleets (Japan and Poland) had fished in Subarea 48.1 in recent years, and their mean catch rate in January to March 2000 was higher than that reported in January to March 1999 (Fig. 8). Furthermore, the mean catch rate for the Japanese-flagged trawlers over the period January to March 2000 (135 t/day) was the second highest reported in the 19-year time series available for that fleet (range: 38–153 t/day). Similarly, the mean catch rate for the Polish-flagged trawlers during January to March 2000 (33 t/day) was the third highest reported in the 8-year time series for that fleet (range: 18–37 t/day).

2.2. *Commercial harvest of the Chiyo maru No. 5*

Under the auspices of CCAMLR, a formal bilateral agreement between the governments of Japan and the United States was implemented prior to the CCAMLR 2000 Survey. This agreement enabled a US scientist to conduct scientific observations aboard the Japanese-flagged trawler *Chiyo maru No. 5*. The *Chiyo maru No. 5* fished for krill in Subarea 48.1 from January 31 to March 1, 2000, overlapping with the CCAMLR 2000 Survey, and a regional acoustic krill survey conducted by the US AMLR program in Subarea 48.1 from February 22 to March 7, 2000 (Emery et al., 2001). This section summarizes the findings of the scientific observations aboard the *Chiyo maru*

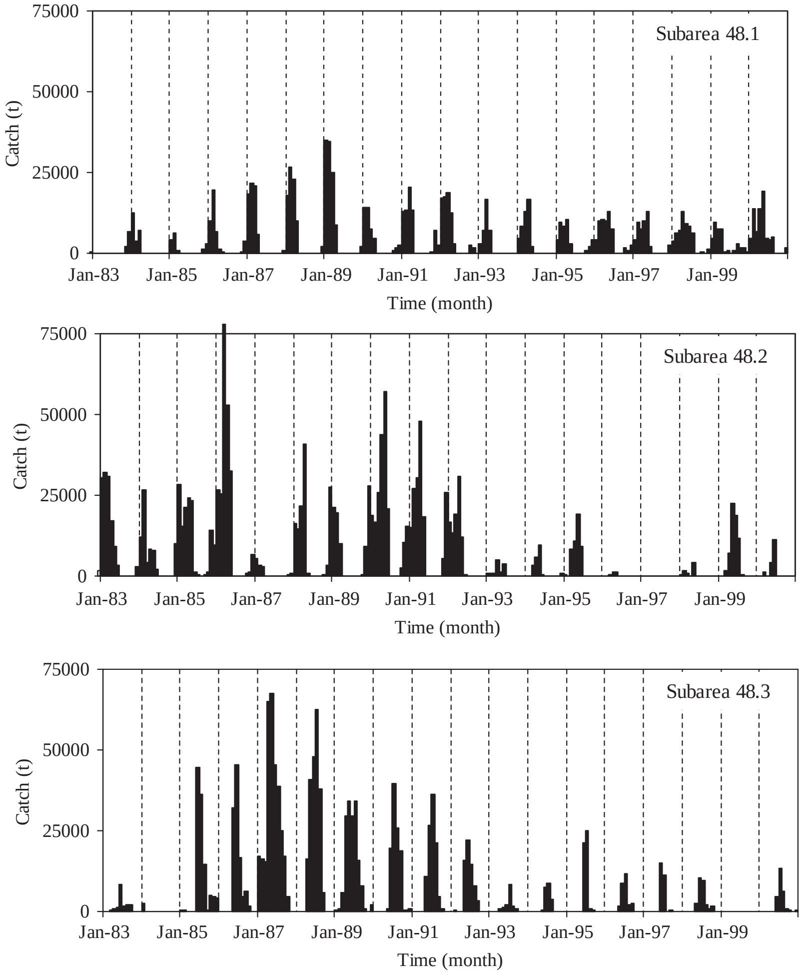

Fig. 4. Monthly catch (t) of krill reported from the southwest Atlantic (Subareas 48.1, 48.2, 48.3) between January 1983 and December 2000. Source: STATLANT data, CCAMLR.

No. 5, and compares the commercial catches with the outcome of the two acoustic surveys.

During its voyage, the *Chiyo maru No. 5* conducted a total of 252 commercial hauls targeting krill in waters to the north of Elephant Island and the western part of the South Shetland Islands (Fig. 9). Detailed information on hauling operations was reported by Rain (2000). The trawls used by the *Chiyo maru No. 5* were pelagic (mid-water) trawls, with progressively smaller mesh diameter toward the codend. The codends were double-layered, with the meshes of the inner sleeve approximately 20 mm, stretched diameter. The external, intermediate panels of the nets were constructed of knotless mesh panels. Fishing operations were conducted around the clock and the average tow duration was 39 min. The target depth of the hauls averaged 39 m (range 1–140 m), and there was a tendency to fish in shallower water between 1800 and 0600 h (local time), and deeper water between 0600 and 1800 h. The bottom depth is the region ranged from 100 to 4000 m.

Haul locations were categorized into five regions, based on tow location cluster and fishing depth (Fig. 9). Region 1 consisted of seven hauls taken during the first fishing day, and was located

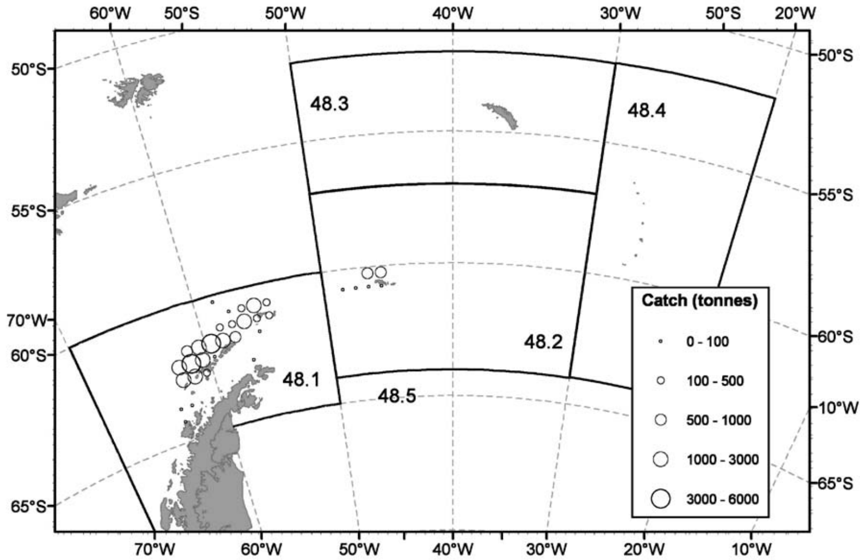

Fig. 5. Commercial catch (t) of krill reported in Area 48 between January and March 2000. Catches are aggregated by fine-scale (0.5° latitude by 1.0° longitude) rectangles. Source: CCAMLR (2001a).

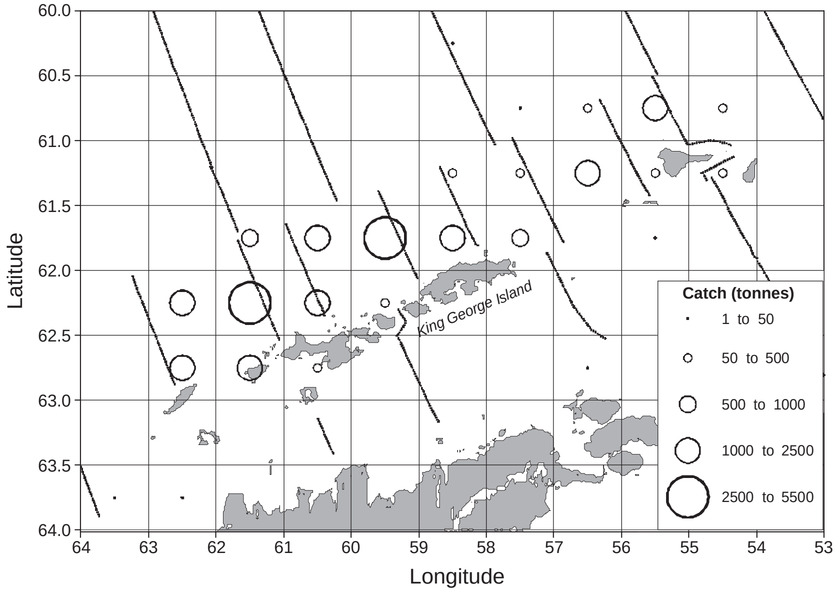

Fig. 6. Commercial catches (t) aggregated by fine-scale (0.5° latitude by 1.0° longitude) rectangles from January to March 2000 in Subarea 48.1. Overlaid are the track lines from the CCAMLR 2000 Survey.

north of Elephant Island in waters with a bottom depth of 3000 to 3500 m. Region 2 was located northwest of Elephant Island, and consisted of 33 tightly clustered hauls in water depths of 3500 to 4000 m; this was the deepest and most offshore of the five regions considered. Region 3 consisted of

Table 1
Reported commercial catch and acoustic density of krill in Subarea 48.1 by fine-scale rectangle for the period January to March 2000

Fine-scale rectangle coordinate (° S)	Fine-scale rectangle coordinate (°W)	Reported krill catch (t)	Mean krill density (g/m^2)	Rank of catches	Rank of mean densities
62.0	61.0	5356	47.8	1	4
61.5	59.0	3321	22.4	2	8
62.5	62.0	2192	14.5	3	10
62.0	60.0	2060	17.0	4	9
62.5	61.0	1976	187.1	5	1
61.5	58.0	1894	14.4	6	11
60.5	55.0	1528	7.5	7	17
62.0	62.0	1119	5.0	8	20
61.5	60.0	1100	24.7	9	7
61.0	56.0	1041	10.0	10	15
61.5	57.0	706	32.2	11	5
61.5	61.0	541	51.7	12	3
60.5	56.0	451	7.5	13	18
60.5	54.0	382	0.0	14	23
61.0	54.0	231	11.0	15	14
61.0	58.0	166	4.9	16	21
61.0	55.0	156	29.6	17	6
61.0	57.0	144	62.7	18	2
62.0	59.0	94	6.1	19	19
60.5	57.0	12	0.1	20	22
63.5	63.0	9	12.8	21	13
60.0	58.0	6	8.5	22	16
62.5	56.0	1	13.6	23	12

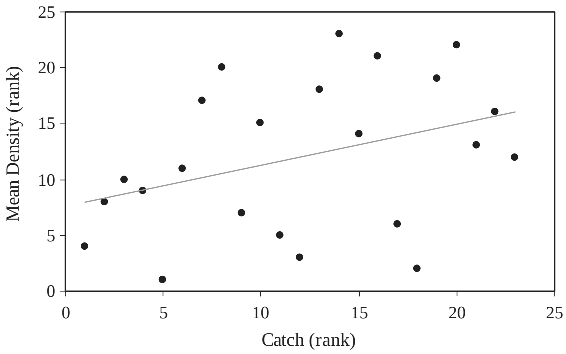

Fig. 7. Spearman rank correlation between catches of krill reported in 23 fine-scale rectangles traversed during the CCAMLR 2000 Survey and the corresponding mean densities of krill estimated from the survey ($r_s = 0.366$; $n = 23$; $P < 0.10$, rank 1: highest value; rank 23: lowest value).

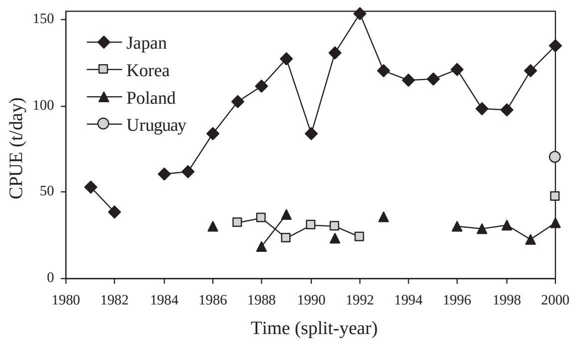

Fig. 8. Mean catch rates for krill (t/day) in Subarea 48.1 during January to March of each split-year. Source: STATLANT data, CCAMLR.

73 hauls in an area located directly north of Livingston Island with a bottom depth of 100 to 250 m; this was the most shallow and inshore region. Region 4 included 54 hauls located north-west of Livingston Island in waters of 1000 to 1500 m. This region also included seven hauls in waters with bottom depths of 250 to 500 m. Finally, Region 5 consisted of 85 hauls in waters

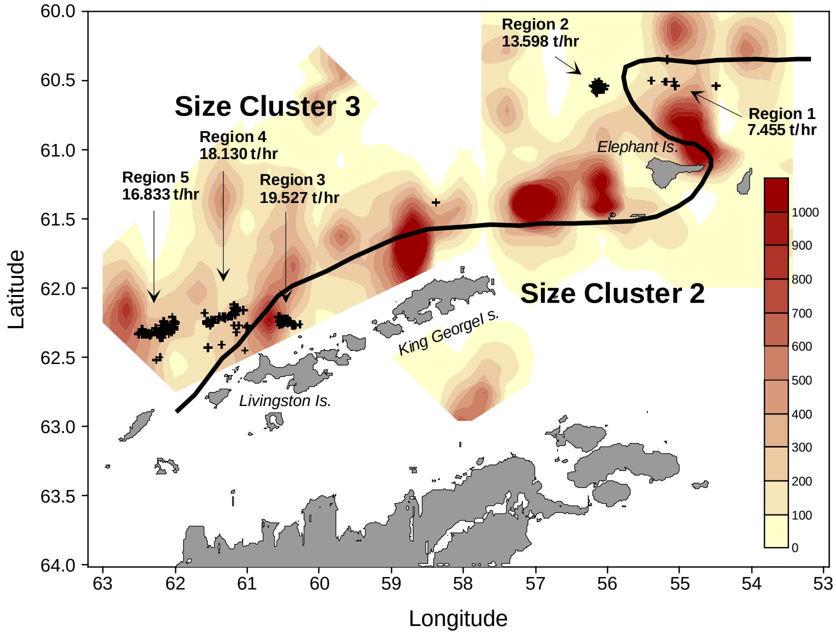

Fig. 9. Location of hauls made by the trawler *Chiyo maru No. 5* between January 31 and March 1, 2000. The shaded regions represent krill densities estimated from the US AMLR acoustic krill survey conducted between February 22 and March 7, 2000 (Emery et al., 2001). The units are integrated nautical area scattering coefficient (m^2/nm^2) at a frequency of 120 kHz (proportional to krill abundance). The solid line represents the boundary between krill size clusters observed during the CCAMLR 2000 Survey (Siegel et al., 2004).

Table 2
Catch information by region for krill captured during fishing operations of the *Chiyo maru No.5*. Mean catch rates are on a haul-by-haul basis, and have been adjusted to tonnes per hour trawled

	Region					
	1	2	3	4	5	All sets
Total catch (t)	43	358	755	547	826.5	2529.5
Mean catch rate (t/h)	7.46	13.60	19.53	18.13	16.83	17.21
Range catch rate (t/h)	9.73	24.40	52.91	79.20	46.00	82.91
Minimum catch rate (t/h)	3.60	3.60	1.09	4.80	4.00	1.09
Maximum catch rate (t/h)	13.33	28.00	54.00	84.00	50.00	84.00
Number of hauls	7	33	73	54	85	252
Bottom depth (m)	3000–3500	3500–4000	100–250	1000–1500[a]	1500–2500	

[a]In addition, seven hauls were made in waters of 250 to 500 m bottom depth.

with bottom depths of 1500 to 2500 m to the west-northwest of Livingston Island. A single haul was made north of King George Island but was excluded from further analysis.

The total catch of krill from all hauls was estimated at 2530 t. Most of this was taken in Region 5 (Table 2, Fig. 9), where the largest number of hauls within a cluster occurred. However, the highest nominal catch rate (t/h) was in Region 3 (Table 2, Fig. 9). Significant differences were evident in catch rates between regions. Regions 3 to 5 had significantly higher variability and mean catch rates than Region 2 (*F* test series, ANOVA $P<0.0001$). In addition, Region 3 had significantly higher catch rates than Region 5 (although not Region 4).

The US AMLR acoustic survey covered all regions of the South Shetland Islands fished by the *Chiyo maru No. 5*. The timing of the US AMLR survey and the trawler's fishing operations overlapped by nine days, at which time the scientific observer on board the trawler visually sited the US AMLR survey vessel off the lower South Shetland Islands. This is allowed for a semi-real-time comparison of the findings of the US AMLR scientific survey with those of the directed trawl fishery. When the densities estimated from the scientific survey (Emery et al., 2001) are overlaid with the commercial haul locations, the regions with the highest catches and catch rates of krill from the commercial trawler correspond to areas where the survey detected high densities of krill (Table 2; Fig. 9), with the exception of Region 1, which had the lowest catch and catch rate of any region.

The number of sets, spatial distribution, and catch rates of hauls in Region 1 differed substantially from the fishing pattern observed in other regions, and the poor fishing success in Region 1 may have been a result of the initial 'shake down' period on the first day of the commercial fishing expedition. Fig. 9 also demonstrates that the commercial fishing operations did not necessarily target the highest densities of krill. The greatest concentrations appeared just to the northeast of Elephant Island, as well as to the north of King George Island. However, Ichii et al. (1996) noted that the krill fishery is not active near the northern coasts of King George Island where krill are often abundant, since numerous rocks discourage fisherman from trawling these areas. In addition, Hewitt et al. (1994) suggest that poor correlation of local areas of high krill density and location of fishing effort may imply rapid change in local krill abundance. Thus, the concentrations detected by the commercial hauls targeting krill represent only a small fraction of the true spatial distribution of concentrations. It should be noted that some additional uncertainty arises owing to an overlap of only 9 days during the US AMLR survey and the fishing operations of the *Chiyo maru No. 5*. However, this underscores the importance of scientific survey design in characterizing the distribution and biomass of krill.

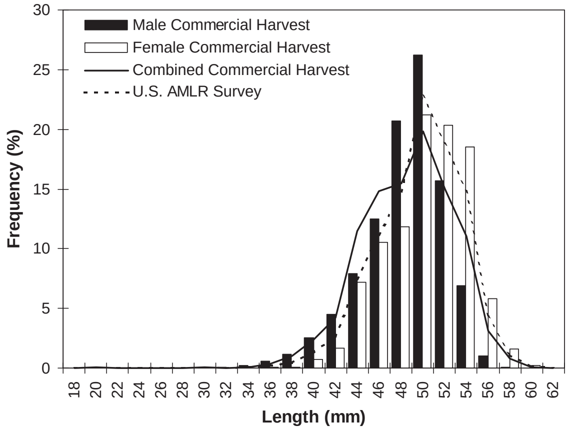

Fig. 10. Body length (mm) of krill by sex sampled aboard the *Chiyo maru No.5* from January 31 to March 1, 2000 and during the US AMLR acoustic krill survey conducted during February 22 to March 7, 2000 (Emery et al., 2001).

Length measurements were taken from a total of 12,984 krill across all regions. Measurements of body length (AT) of krill were taken from the front of the eye to the tip of the telson, and to the nearest millimeter below. Measured lengths by sex from the *Chiyo maru No.5* and net sampling from the US AMLR acoustic krill survey are presented in Fig. 10. The average length from all krill measured was 49.1 mm, with a modal length of 50 mm. Lengths ranged from 18 mm to 62 mm.There was no difference in variability of lengths between sexes, and mean lengths of females were significantly higher than males (*t*-test, $P<0.0001$) for combined samples.

The overall length–frequency distribution of krill caught during the fishing operations of the *Chiyo maru No. 5* agreed with the distributions of krill collected in net samples from the US AMLR survey (Fig. 10), as well as with krill collected around the South Shetland Islands during the CCAMLR 2000 Survey (Siegel et al., 2004). The majority of the krill captured during fishing operations were adults, probably centered on an age 4 or 4+ year class. Length–frequency distributions by region demonstrated some distinct

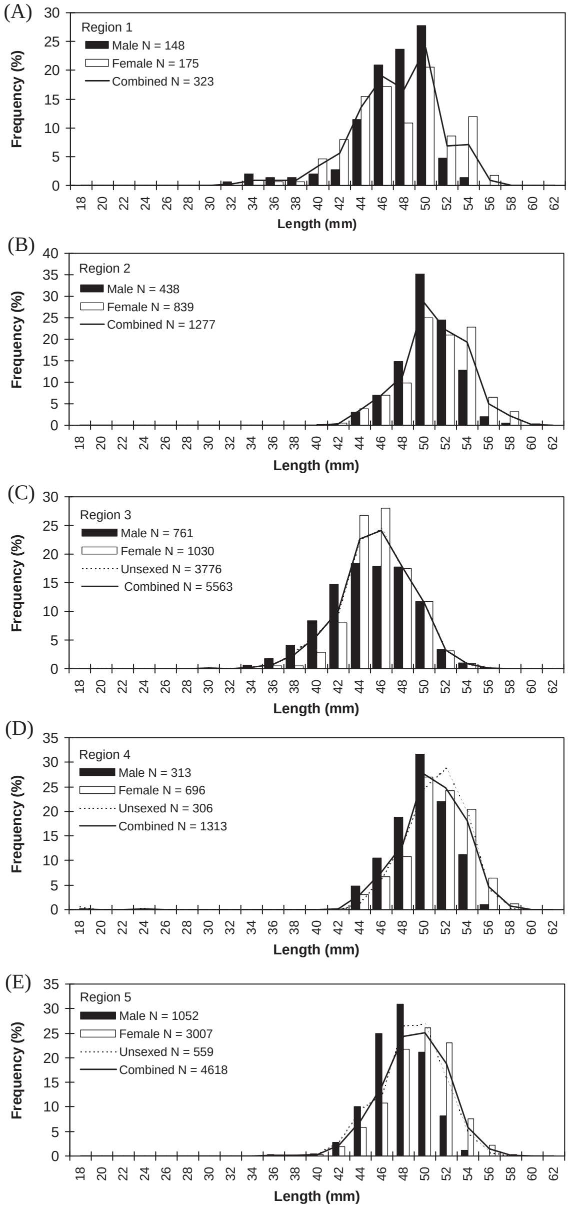

Fig. 11. Length–frequency distribution of krill by region fished by the *Chiyo maru No.5* from January 31 to March 1, 2000.

differences in size (Figs. 11A–E). The krill in Region 3, the most inshore and shallow region, had significantly smaller ($P<0.0001$) mean, median, and modal length than krill caught in the other regions (Table 3; Fig. 11C).

The length–frequency distributions of krill measured on board the *Chiyo maru No. 5* also were compared with those of the CCAMLR 2000 Survey (SC-CAMLR, 2000). Three size clusters were identified in Area 48 based on an analysis of measured krill from the survey (Siegel et al., 2004). Regions 2, 4, and 5, which were fished by the *Chiyo maru No. 5*, corresponded with the geographic extent of size cluster 3 from the CCAMLR 2000 Survey, while Regions 1 and 3 were located in cluster 2 (Fig. 9). Although the survey transects in this subarea were conducted primarily in January 2000, the length–frequency distribution of krill in Regions 1 and 3 agreed well with that of size cluster 2 from the CCAMLR 2000 Survey (Siegel et al., 2004), indicating that krill in these regions were mainly 4-year old animals. In this case, the period between the survey's transect measurements and the observer's measurements appeared to be negligible such that the species demography was minimally affected. The size composition of krill from other regions also largely agreed with the findings of the CCAMLR 2000 Survey, although modal lengths were slightly less (50 mm mean aboard *Chiyo maru No. 5*, 52 mm mean for the CCAMLR 2000 Survey). The *Chiyo maru No. 5* did not fish in regions where Siegel et al. (2004) positioned boundaries for krill of size cluster 1.

The maturity stages of 4841 krill were evaluated using the Makarov and Denys (1980) scale described in the CCAMLR Scientific Observer's Manual (CCAMLR, 2001b). Rain (2000) summarized the overall findings. Krill sampled had a strong bimodal maturity-frequency distribution with peaks at stage II (subadults) and stage V (spawning); all groups were represented, although there were very few juveniles ($n=8$). There were significant regional differences in maturity stage (Figs. 12A–D). Region 1 was excluded from this comparison because maturity stages were not sampled in this area. Region 3 mostly comprised subadult krill (stage II, Fig. 12B), while krill in Regions 2, 4, and 5 were mostly fully gravid or in spawning condition (Figs. 12A, C and D). This is not unexpected, since Region 3 was the most inshore region and catches had a greater proportion of small krill (Fig. 11C). The maturity distribution of krill in Region 2 (Fig. 12A)

Table 3
Size composition of krill sampled in each region fished by the *Chiyo maru No.5* from January 31 to March 1, 2000

	Region 1	2	3	4	5	Combined
Mean (mm)	47.3	51.0	45.5	50.7	48.9	48.6
Standard error	0.228	0.087	0.048	0.089	0.046	0.037
Median	48	50	46	50	50	48
Mode	50	50	46	50	50	50
Sample variance	16.8	9.7	12.7	10.5	9.7	17.9
Minimum	32	40	18	18	36	18
Maximum	56	60	58	58	60	60
Sample size	323	1277	5563	1313	4618	13094

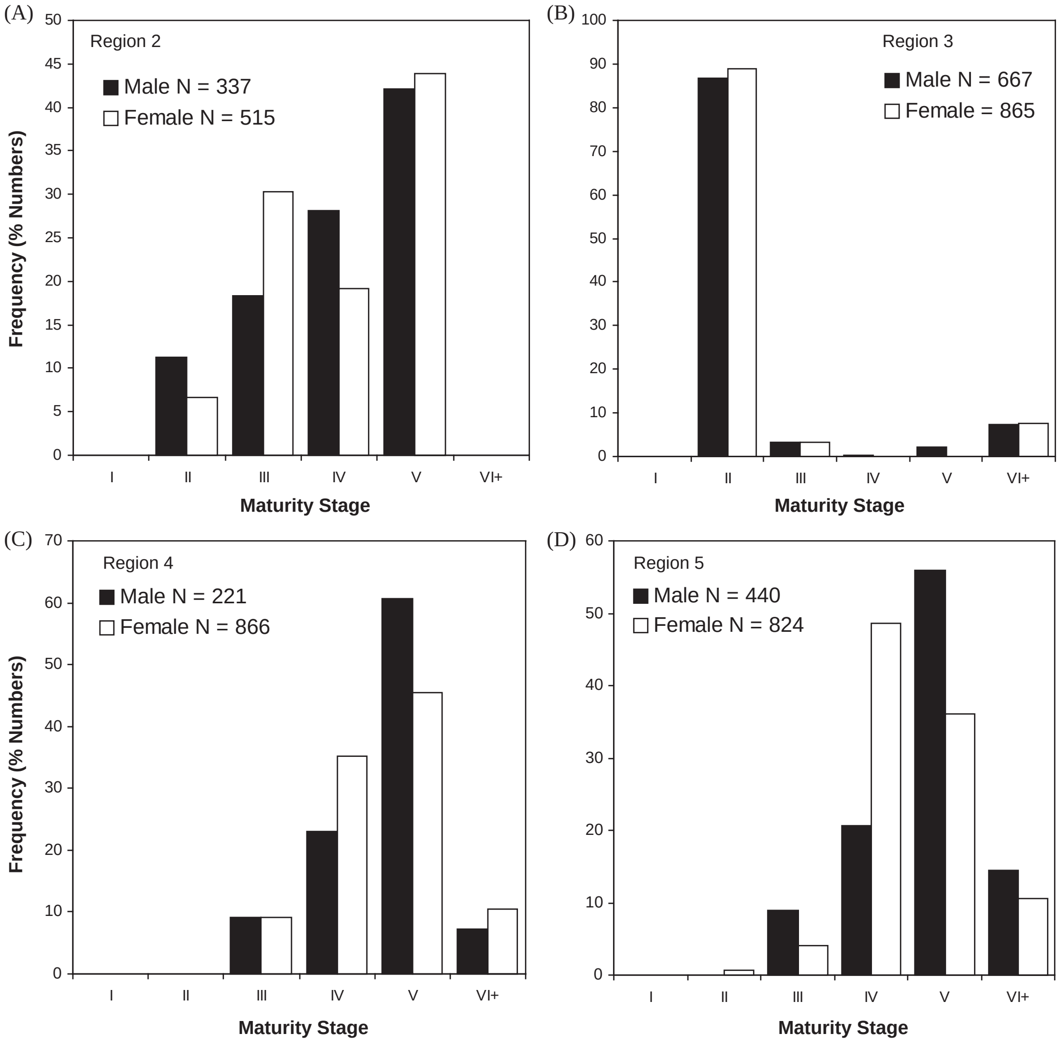

Fig. 12. Maturity stages of krill by region fished by the *Chiyo maru No.5* from January 31 to March 1, 2000.

comprised less mature krill than Regions 4 and 5, and did not contain krill that had transitioned to the resting stage (VI+). This was probably due to the time of sampling within Region 2, which was well before the trawler had moved to fish in Regions 4 and 5.

3. Discussion and conclusions

The krill fishery in the southwest Atlantic is characterized by a seasonal pattern in fishing, with vessels targeting krill in waters adjacent to South Georgia (Subarea 48.3) during the austral winter, and moving southward to fish at the South Shetland Islands (Subarea 48.1) and South Orkney Islands (Subarea 48.2) during summer. At the time of the CCAMLR 2000 Survey (January and February 2000), vessels were fishing for krill primarily in Subarea 48.1. There was very limited activity in Subarea 48.2, and no fishing was reported from other subareas in Area 48. However, results from the CCAMLR 2000 Survey indicated high krill densities around the South Orkney Islands (Subarea 48.2) and the South Sandwich Islands (Subarea 48.4). The fishery appeared to be operating in an area where, according to the CCAMLR 2000 Survey, there were moderate krill densities (Siegel et al., 2004). Thus, there was significant biomass of krill found in areas never targeted by the fishery. It is therefore likely that the fishery was targeting high densities of krill of a certain size and color rather than absolute high density—hence possible differences between areas targeted by the fishery and 'hot spots' identified during the CCAMLR 2000 Survey.

The *Chiyo maru No. 5* targeted Subarea 48.1 (as opposed to other subareas within Area 48) for commercial fishing during this period because the captain of the vessel noted from previous experience that krill tend to be intensely green in Subarea 48.3 during the austral summer, and krill concentrations tend to be less stable in Subarea 48.2 during this period. Decisions by the captain to fish certain areas within Subarea 48.1 (thus determining the spatial distribution of haul clusters) were probably often based on factors other than maximum krill biomass; such as salp by-catch, greenness, body color, condition, and size of krill (Ichii, 1987; Jones and Hull, 2002; Kawaguchi and Segawa, 2001), and depth/seafloor characteristics. However, a good correlation was found between the spatial distributions in abundance, size, and maturity of krill caught in the commercial fishery in Subarea 48.1 at the time of the CCAMLR 2000 Survey and the US AMLR survey, and the corresponding distributions observed during those surveys.

The size and maturity patterns of krill sampled from the commercial catches of the *Chiyo maru No. 5* showed distinct differences between regions fished. While true that inferences drawn from a directed fishery can be misleading due to the non-randomness of the fishing operation, the present study clearly indicates that the collection of biological data from fishing trips can be beneficial to the understanding of the fished population. It is important to emphasize how well the krill sampled during the fishing operation of the *Chiyo maru No. 5* agreed with the patterns of size and maturity described from the CCAMLR 2000 Survey and the US AMLR krill survey. However, this is not necessarily an indication that in all cases the size distribution of survey data will be an indication of the distribution of commercial catches, and vice versa. This is primarily because different sized nets can have different selectivities, and thus may influence the size distribution of krill in the catch. A large trawl will probably catch a more representative sample of the krill aggregation than a plankton net; unless the mesh size is such that the small krill escape. In the present case, neither the commercial nor the survey nets appeared to capture the smallest year classes, if indeed they were present in the area.

The distribution of krill catches taken in the fishery in Subarea 48.1 between January and March 2000 was also significantly correlated ($P<0.10$) to the density of krill observed in the CCAMLR 2000 Survey. Although not available for use in this study, CCAMLR does hold more detailed catch and effort data for the krill fishery, with data reported by 10×10 nm rectangles and by 10-day period, or on a haul-by-haul basis. Had haul-by-haul data been available for all vessels engaged in the fishery at the time of the surveys, then it may have been possible to examine the relationship between the fishery and the surveys in greater detail.

The present findings indicate that the abundance of krill in Subarea 48.1, as estimated from catch rates in the fishery, appeared to be high during the period of the CCAMLR 2000 Survey. The Japanese fleet reported the second highest mean catch rate in the 19-year time series of data, and the Polish fleet reported the third highest mean catch rate in 8 years of fishing. However, based on a time series of acoustic surveys conducted by the US AMLR program off the South Shetland Islands from 1991/1992 to 2001/2002, Hewitt et al. (2003) suggest that there is a cyclical pattern in krill biomass in this region, and that 2000 represented an average level of biomass within this cycle. Thus, the relationship between catch rates of commercial fleets and estimates of abundance from fishery-independent scientific surveys remains a complex issue which requires further study and additional data on all aspects of the krill fishery, including decision making processes that influence the pattern of fishing effort by the commercial vessels.

Countries involved in the krill fisheries of the Southern Ocean should be strongly encouraged to use scientific observers so that information of the type collected aboard the *Chiyo maru No. 5* can be gathered on a regular and consistent basis, leading to a better understanding of long-term change and population dynamics for krill in the Southern Ocean.

Acknowledgements

We sincerely thank Wolfgang Rain (US observer), the Japan Deep Sea Trawlers Association, and Tetsuo Inoue, So Kawaguchi, Roger Hewitt, and Jennifer Emery for their valuable contributions to this paper.

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